Benefit measurement of the soil and water conservation for ecological forestry engineering

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Abstract: Data were collected from Three-north Region, Middle and upper reaches region of Yangtze River and Coastal region. By analysis of factors influencing soil erosion, the longitude, latitude, annual precipitation, and the slope degree were selected as regional independent variables and canopy density and stock litter were selected as independent variables, and integral diffusing models were established for evaluation of the benefit of soil and water conservation of forest. By solving the parameters of models using the package of STATISTICA, the Power function between independent variables and dependent variables was set up. The soil conservation amount of forest and economic values were estimated using the contrast method for the ecological forestry engineering of the above three areas.

Key words: Ecological forestry engineering; Soil and water conservation; Benefit measurement; Integral diffusing model
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Introduction

The loss of water and soil has been the global problem. Its total area is 25 million km^2. or 16.8% of global land area. The fertile surface soil of 60 billion t flows into rivers each year. Because of soil corrosion, the land of 210 billion hm^2 has lost fertility and cannot be used as agricultural land. Human recognizes the severity of loss of water and soil while he uses land resources. The different measures are being taken in order to increase soil and water conservation. Several ecological forestry engineerings have been carried out In China for environment conservation. The Three-North Protective Plantation, Protective Plantation of Middle and Upper Reaches Area of Yangtze River and the Coastal Protective Plantation are the most important projects of ecological forestry engineering. The benefits of the ecological forestry engineering on soil and water conservation were measured and evaluated with integral diffusing models in this study.

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Site and date Collection

Three-North Protective Plantation

The Three-North Protective Plantation System Project started in 1978, and was approved by the Chinese Government. It is aimed at building up an ecological and economical protection forest system on severely sand blown and soil eroded areas of Three-North and contributing to coordinating the development of agriculture, forestry and animal husbandry. The project includes northern, northeastern, northwestern regions in China, covers a land area of 4.069 M km^2, or 42.4% of the total land area of China, between longitude 73°26' and 127°50' E and latitude 33°30' and 50°12' N, with a length from east to west of 4480 km and a width from north to south of 1460 km. 551 counties, distributed in Shaanxi, Ganshu, Ningxia, Qinghai, Xinjiang, Shanxi, Hebei, Beijing, Tianjin, Inner Mongolia, Liaoning, Jilin, and Heilongjiang provinces are involved in the project (Zhang 1993). Relief of western region is higher than that of eastern region. Elevation varies from 100 to 5000 m. Precipitation decreases from east to west and from south to north.

The protective plantation project of the middle and upper reaches area of Yangtze River

The total length of Yangtze River is 6300 km, with a drainage area of approximately 1.80 million km^2 and

a forest coverage rate of 20.7%. Mountain and plateau occupy more than 90% of middle and upper reaches region and hills and plains are less than 10% (Zhang 1993). Annual precipitation is from 800 to 1800 mm, averaging 1100 mm. The protective plantation project of the middle and upper reaches area of Yangtze River is located between longitude 59° and 112° E and latitude 25° and 35° N. The first term of project planted 7.43 million hm^2 of trees.

Coastal protective plantation

The coastal region is located in east, southeast of China, between latitudes 18°~41°40' N and longitude 108°~124°30' E. It includes 195 counties, distributed in Liaoning, Heibe, Tianjin, Shandong, Shanghai, Fujian, Zhejiang, Guangdong, Guangxi and Hannan provinces (Zhang 1993). Its length is 18000 km. Annual precipitation is from 600 to 2800 mm, and it increases from north to south. The total area is 25.0696 million hm^2 (Zhang 1993). The area of the coastal protective plantation is 0.82 million hm^2.

Date collection

Data on longitude, latitude, precipitation, slope, stand type, litter, soil loss, and so on were collected in the above mentioned regions. Their attribute statistics are presented in Table 1 and Table 2.

Table 1. The attribute statistics of forest land

Variables	N	Mean	Min.	Maxi.	Standard deviation
Longitude (°)	80	114.46	99.88	128.88	9.343
Latitude (°)	80	35.47	18.50	47.17	7.806
Precipitation, mm	80	543.74	50.70	1588.6	395.02
Slope (°)	80	17.60	6.38	26.00	5.53
Canopy density, %	80	63.8	30.0	85.0	14.81
Litter, t/hm^2	80	35.08	7.68	72.60	7.87
Soil loss,t/hm^2 · a	80	33.44	0.51	149.80	44.12

Table 2. The basic statistics of non-forest land

Variables	N	Mean	Minimum	Maximum	Standard deviation
Longitude (°)	52	104.51	98.33	129.28	5.22
Latitude (°)	52	32.00	23.95	42.98	4.57
Precipitation, mm/a	52	977.44	103.20	1356.00	471.87
Slope (°)	52	16.30	5.00	26.00	5.51
Soil loss,t/hm^2 · a	52	13.12	1.36	39.16	9.82

Index system and integral diffusing model

Index system of benefit measurement

According to the sduty by Lang *et al* study (2000), the factors effecting loss of water and soil are divided into regional factors and stand factors. Regional factors include longitude, latitude, annual precipitation (mm), slope. Stand factors include stand type, stand age, canopy density and stock litter. Regional factors and stand factors are as independent variables to measure the loss of water and soil, in which stand type and stand age group are qualitative factors and cannot be quantitatively studied. The measuring indices are set up as follows:

(1) Dependent variable: soil loss (t/hm^2 · a)

(2) Regional independent variables: longitude [°], latitude(°), annual precipitation (mm), slope [°]

(3) Stand independent variables: canopy density (%), stock litter (t/hm^2).

Integral diffusing model of benefit measurement

According to Zhang *et al* study (2000) and fitting results of data using STATISTICA package, the Power equation is selected to set up Integral diffusing model.

Integral diffusing model of forest land

$$y = a \cdot \exp(b \cdot x_1) + c \cdot \exp(d \cdot x_2) + e \cdot \exp(f \cdot x_3) + g \cdot \exp(h \cdot x_4) + i \times \exp(j \cdot x_5) + k \cdot \exp(l \cdot x_6) \quad (1)$$

where:

y--soil loss of forest land, t/hm^2 · a;
x_1--longitude, [°];
x_2--latitude, [°];
x_3--precipitation, mm/a;
x_4--slope, [°];
x_5--canopy density, %;
x_6—stock litter, t/hm^2;
a, b, c, d, e, f, g, h, l, j, k, l are parameters.

Using package of STATISTICA, parameter estimates of integral diffusing model for forest land is presented in Table 3.

Table 3. Parameters and its estimates of integral diffusing model for forest land

Parameters	a	b	c	d	e	f
Estimates	55.57	-2.29	0.000001	0.4318	0.000013	0.0115
Parameters	g	h	i	J	k	l
Estimates	211.55	-0.054	-306.89	-2.5105	-161.896	-0.904
Correlation coefficient			0.8517			

Integral diffusing model of non-forest land

$$y=a\cdot\exp(b\cdot x_1)+c\cdot\exp(d\cdot x_2)+e\cdot\exp(f\cdot x_3)+ g\cdot\exp(h\cdot x_4) \quad (2)$$

where:

y—soil loss of forest land, t/hm^2 • a;

x_1—longitude, [°];

x_2—latitude, [°];

x_3—precipitation (mm/a);

x_4—slope, [°];

a、b、c、d、e、f、g、h—parameters.

Using package of STATISTICA, Parameter estimates of integral diffusing model for non-forest land is presented in Table 4.

Table 4. Parameter estimate of integral diffusing model for non-forest land

Parameters	a	b	c	d
Estimates	0.00002	0.41113	-117.214	-2.6323
Parameters	e	f	g	h
Estimates	0.16603	0.00285	0.84068	0.06991
Correlation coefficient		0.9105		

Benefit measurement

Physical benefit

With contrast method, the samples of regional independent variables and stand independent variables were selected in three ecological forestry engineering regions mentioned above. We put these samples in equation (1), then we got soil loss amount of forest land. We put only samples of regional independent variables in equation (2), then we got soil loss amount of non-forest land. The difference of them is soil and water conservation amount. The results are presented in Table 5.

Total physical benefit amount (t) of the soil and water conservation equals area of forest land (hm^2) timing soil conservation per hectare (t/hm^2). Results are presented in Table 6.

Economic benefit

Based on the cost of building the barrage with the same effect having the soil and water conservation (0.3 yuan/t) (Chen 1984), the economic value of the soil and water conservation for three ecological forestry engineering is account. Results are presented in Table 7.

Table 5. Physicla benefit measurement of the soil and water conservation

Variables	Three north region		Middle and up reaches region of Yangtze River		Coast region	
	n	mean	n	mean	n	mean
Soil loss of non-forest land, t/hm^2	18	99.32	25	329.54	25	59.79
Soil loss of forest land, t/hm^2	18	6.76	25	97.77	25	13.16
Soil conservation, t/hm^2	18	92.53	25	231.77	25	46.63

Table 6. Total physical benefit amount of the soil and water conservation

Item	Three north region	Middle and upper reaches region of Yangtze River	Coastal region
Soil conservation per hectare, t/hm^2	92.5297	231.7686	46.625
Area of forest land, hm^2	4085300	1037700	1760700
Total soil conservation, t	3.78×10^8	2.41×10^8	0.82×10^8

Table 7. Economic benefit measurement of the soil and water conservation

Item	Three north region	Middle and upstream region of Yangtze River	Coastal region
Value per hectare, yuan/hm^2	27.76	69.53	13.99
Total area of forest land, hm^2	4085300	1037700	1760700
Total value, yuan (RMB)	1.134×10^8	7.22×10^7	2.463×10^7

Conclusion

Through analysis of factors, it is confirmed that the soil and water loss is resulted from synthetic effect of multiple factors. The soil and water loss varies with different regions and different forest types. Longitude, latitude, annual precipitation, slope and stand are selected and defined as regional independent variables, stand types, stand age, canopy density and stock litter as independent variables.

By contract method, the data of forest and non-forest land were calculated using STATISTICA package. The Power equation is used to set up the integral diffusing model.

By calculation, the physical benefit measurement of the soil and water conservation of Three-north region, Middle and upper reaches region of Yangtze River and Coastal region is 3.78×10^8 t, 2.407×10^8 t, and 0.821×10^8 t respectively, while converting to economic values (RMB), it is 1.134×10^8 yuan, 7.22×10^7 yuan and 2.463×10^7 yuan respectively for the three regions.

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